

# Predictors of early stem loosening after total hip arthroplasty: a case-control study

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## ABSTRACT

**Purpose.** To evaluate the influence of patient characteristics on stem loosening after cemented or uncemented total hip arthroplasty (THA) using a matched case-control study.

**Methods.** Consecutive records of 4372 cemented (716 cases and 3656 controls) and 809 uncemented (115 cases and 694 controls) primary THAs between 1981 and 2003 in 30 hospitals in 8 European countries were reviewed. Cases and controls were defined as patients with and without stem loosening, respectively. In cases of bilateral THA, patients were their own controls. Cases and controls were matched for hospital, date of surgery, date of follow-up, stem type, and head size. Patient characteristics such as gender, age, weight, height, body mass index (BMI), diagnosis, presence of previous surgery on the affected hip, and walking restrictions according to the Charnley classification were recorded.

**Results.** Male patients were at higher risk of cemented stem loosening (odds ratio [OR], 1.76; 95% confidence

interval [CI], 1.4–2.2). Older patients were at lower risk of cemented stem loosening; the odds decreased by 3% per year older (OR, 0.97; 95% CI, 0.96–0.98). Regarding BMI, the odds of cemented stem loosening increased by 3% for each additional unit of BMI over 25 kg/m<sup>2</sup> (OR, 1.03; 95% CI, 1.004–1.05). Patients in Charnley class B had a lower risk of cemented stem loosening (OR, 0.75; 95% CI, 0.61–0.93).

**Conclusion.** Advanced age, female gender, and Charnley class B (as a proxy measure of reduced walking activity) have a protective effect on survival of cemented stems, whereas a higher BMI was a risk factor.

**Key words:** arthroplasty, replacement, hip; hip; prosthesis failure; risk factors

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## INTRODUCTION

Aseptic loosening of the femoral or acetabular component of total hip arthroplasty (THA) remains the most common complication necessitating revision. The influence of patient characteristics on long-

term results and implant failure has been studied.<sup>1,2</sup> Advanced age and female gender have a protective effect on survival of the acetabular component, independent of the fixation mode.<sup>3</sup> A high body mass index (BMI) increases the risk of loosening of the uncemented cup only. We evaluated the influence of patient characteristics on stem loosening after cemented or uncemented THA using a matched case-control study.

## MATERIALS AND METHODS

Pre- and post-operative clinical and radiological findings of 4372 cemented (716 cases and 3656 controls) and 809 uncemented (115 cases and 694 controls) consecutive primary THAs between 1981 and 2003 in 30 hospitals in 8 European countries (Austria, Belgium, Switzerland, Germany, France, Netherlands, Spain and Italy) were retrieved from the database of the Institute for Evaluative Research in Medicine at the University of Berne, Switzerland. Patients aged >20 years who had diagnosis of osteoarthritis, developmental dysplasia, inflammatory arthritis, fracture, or osteonecrosis and were followed up for >1 year, with a complete set of anteroposterior and lateral pelvic radiographs or with a revision for stem failure were included.

Stem loosening was defined as stem subsidence of  $\geq 3$  mm,<sup>4</sup> radiolucencies of >2 mm or continuous at the bone-stem or bone-cement interface,<sup>5</sup> progressive tilt of the stem, multiple small cavitations or large defects, or stem/cement fracture.<sup>6</sup>

Controls were patients who had no radiographic signs of stem loosening. In cases of bilateral THA, patients were their own controls. Cases and controls were matched for hospital, date of surgery (within  $\pm 2.5$  years), date of follow-up (<6 months time difference), stem type, and head size. Respectively in the cemented and uncemented THA groups, 47% and 58% of the patients were males; 11% and 5% had bilateral THA; 6% and 7% had had a previous surgery other than THA on the affected side; the mean follow-up period was 4.4 (range, 0.24–21.7) and 2.7 (range, 0.22–11.1) years; and 39 and 27 stem types were used.

Patient characteristics such as gender, age, weight, height, BMI, diagnosis, presence of previous surgery on the affected hip, and walking restrictions according to the Charnley classification<sup>7</sup> were recorded. Associations between stem loosening/revision and patient characteristics were analysed as a 1:M matched study (multiple controls matched to each case) using multiple conditional logistic models. The first model was fitted to the data to investigate

the overall effects of age and BMI adjusted for gender, diagnosis, Charnley class, and presence of previous surgery. Age and BMI were continuous variables, whereas gender, diagnosis, Charnley class, and presence of previous surgery were categorical variables.

The results of continuous variables were interpreted as an estimate of the change in odds per unit increase of each variable. Because it cannot be assumed that the correlation between predictors and outcome is always linear, additional models were evaluated with continuous variables categorised into groups. BMI was divided into 3 groups: <25 (normal, referent), 25–30 (overweight), and  $\geq 30$  kg/m<sup>2</sup> (obese).<sup>8</sup> Age was divided into 4 groups: <60 (referent), 60–69, 70–80, and >80 years. Weight was categorised into 4 quartiles: <64 (referent), 64–72, 73–82, and >82 kg. Results were interpreted as a risk difference to referents. A further model was used to estimate the significance of all first-order interaction in terms of continuous variables. However, using a backward elimination process, none of the interaction terms appeared to be significant. Power calculations were performed in case of non-significant associations for all exposure levels of age, BMI, diagnosis, and Charnley class.<sup>9</sup> A *p* value of <0.05 was considered statistically significant.

## RESULTS

Respectively in the cemented and uncemented THA groups, the mean patient ages were 66 and 61 years; the mean body weights were 73 and 76 kg; the mean BMIs were 27 and 27 kg/m<sup>2</sup>; and 66% and 72% of the patients were in Charnley class A, 32% and 27% in Charnley class B, and 3% and 1% in Charnley class C.

Male patients were at higher risk of cemented stem loosening (odds ratio [OR], 1.76; 95% confidence interval [CI], 1.4–2.2, Table 1). Power analysis revealed a power of 0.25 for the uncemented arm. 505 cases of uncemented stem loosening would have been necessary to reach a power level of 0.80.

When patient age was analysed as a continuous variable, the odds for cemented stem loosening decreased by 3% per year older (OR, 0.97; 95% CI, 0.96–0.98). Log odds reduction of cemented stem loosening appeared linear across the 4 age groups. A >60% odds decrease (OR, 0.38; 95% CI, 0.22–0.67) was detected for cemented THA patients aged >80 years; the odds decrease was 50% (OR, 0.51; 95% CI, 0.39–0.67) for patients aged 70 to 80 years, and 25% (OR, 0.73; 95% CI, 0.57–0.91) for those aged 60 to 69 years, relative to the younger patients aged <60

years. In the uncemented THA group, risk differences were changing direction and not significant (Table 1). Power levels for the uncemented study arm were underpowered with power levels reaching a maximum of 0.40.

Non-significant and inconsistent influences of body weight on the odds ratio for stem loosening were noted (Table 1). Both study arms were underpowered with only the >82 kg group reaching a power level of 0.80.

Regarding BMI, the odds for cemented stem loosening increased by 3% for each additional unit of BMI over 25 kg/m<sup>2</sup> (OR, 1.03; 95% CI, 1.004–1.05). A similar trend was detected for uncemented stems (OR, 1.03) but was not significant. BMI-related risk profiles of stem loosening increased linearly in both cemented and uncemented THA groups over the observed BMI range, but only became significant in the overweight group (OR, 1.32; 95% CI, 1.02–1.73).

Osteoarthritis was the most common diagnosis for THA and was defined as the referent. Despite differences between cemented and uncemented stems, no significant risk patterns were observed for any of the diagnoses (Tables 1 and 2). All groups were underpowered in both study arms with power levels attaining a maximum of 0.33, except for patients with fracture and cemented stem fixation (power level, 0.93),

Patients in Charnley class A were defined as the referent. Patients in the Charnley class B had a lower risk of cemented stem loosening (OR, 0.75; 95% CI, 0.61–0.93, Table 1). The risk of uncemented stem loosening for Charnley class C could not be evaluated owing to the small number of subjects in this subgroup.

## DISCUSSION

The optimal fixation method for THA (cemented vs. cementless vs. combination of both) remains controversial.<sup>9</sup> Stem fixation for both cemented and uncemented implants has improved significantly over the last 5 decades. Associations between patient characteristics and mechanical stem failure have been studied, but have not focused on fixation modes.<sup>10</sup>

In our study, the risks of stem loosening were estimated using prospectively collected data and conditional multiple logistic regression models. This procedure enabled extensive investigation of various predictors of stem loosening. Strict matching criteria enabled isolation of patient characteristics from other factors (component design or procedure-related factors) and exclusive assessment of each variable's

**Table 1**  
Effects of patient characteristics on stem loosening

Variable	Odds ratio	
	Cemented stems	Uncemented stems
Sex		
Female (referent)	1.00	1.00
Male	1.76*	0.77
Age group (years)		
<60 (referent)	1.00	1.00
60–69	0.73*	1.35
70–80	0.51*	0.74
>80	0.38*	-
Age (as a continuous variable)	0.97*	0.99
Body weight (kg)		
<65 (referent)	1.00	1.000
64–72	1.07	0.978
73–82	0.95	0.761
>82	1.18	1.093
Body weight (as a continuous variable)	1.004	1.00
Body mass index (kg/m <sup>2</sup> )		
<25 (normal, referent)	1.00	1.00
25–30 (overweight)	1.18	1.04
≥30 (obese)	1.32*	1.30
Body mass index (as a continuous variable)	1.03*	1.03
Diagnosis		
Osteoarthritis (referent)	1.00	1.00
Developmental dysplasia	0.82	0.76
Inflammatory arthritis	1.10	0.84
Fracture	0.74	0.52
Osteonecrosis	1.35	1.10
Charnley class		
A (referent)	1.00	1.00
B	0.75*	0.73
C	0.68	-
Previous surgery		
No (referent)	1.00	1.00
Yes	0.90	1.14

\*  $p < 0.05$

**Table 2**  
Distribution of patients in terms of diagnosis and body mass index (BMI)

Variable	No. (%) of cemented/uncemented stems	Mean age (years) of patients with cemented/uncemented stem
Diagnosis		
Osteoarthritis	3558 (81)/613 (76)	67/62
Developmental dysplasia	304 (7)/56 (7)	61/55
Inflammatory arthritis	177 (4)/23 (3)	56/52
Fracture	127 (3)/39 (5)	66/58
Osteonecrosis	206 (5)/78 (10)	62/55
BMI (kg/m <sup>2</sup> )		
<25 (normal)	1622 (37)/303 (38)	-
25–30 (overweight)	1955 (45)/366 (45)	-
≥30 (obese)	795 (18)/140 (17)	-

possible influence on cemented and uncemented stem loosening. The analysis enabled a good generalisation of the results, because multiple centres and prostheses in a long period of time were included.

Influence of gender on stem loosening is controversial. Some studies reported men had more than 2-fold increased risk,<sup>11–13</sup> such that being male is a significant risk factor for the development of osteolysis.<sup>14</sup> Others have found no such association after correction for the effect of body weight.<sup>15</sup> In our previous study, men had a >75% higher risk for cemented stem loosening.<sup>10</sup>

Activity level plays a significant role in prosthesis survival. Men have been reported to have higher loosening rates because of higher activity levels.<sup>16</sup> Nonetheless, when the walking activity in patients with THA is measured, no significant difference between men and women was noted.<sup>17</sup> In addition, higher muscular forces in men and anatomic differences should be taken into consideration, as well as the influence of higher mean BMI in males of most western countries.<sup>18,19</sup>

Advanced age is a protective factor against mechanical stem loosening, irrespective of the fixation mode.<sup>16</sup> Younger age has a negative effect on the durability of THA,<sup>13,20,21</sup> whereby uncemented stems are preferable in this patient group.<sup>22</sup> In our study, in the cemented THA group, a significant risk reduction of 3% per additional year of age was detected. For uncemented THAs, the results were inconsistent. As patients aged <60 years were the referent group, no conclusions for younger patients could be drawn. The inconsistent results of age-related loosening risks in patients with uncemented THA deserve further epidemiological studies. Whether to delay THA should be carefully considered from perspective of outcomes. In addition to age, advanced disease stages also compromise functional results.<sup>16,23</sup> Younger patients with a better preoperative functional status benefit more from the regained mobility, but also expose their prostheses to higher physical strains,<sup>24</sup> which is a reason for higher failure rates. Patients aged <45 and >75 years have a worse prognosis for both prosthesis survival and functional outcome.<sup>21,24,25</sup>

Being overweight or obese contributes to the progression of osteoarthritis.<sup>26,27</sup> Weight is a risk factor for component loosening in THA, but this association remains controversial.<sup>24,28</sup> The decreased

walking activity of such patients may counterbalance the increased stresses on the prosthetic components and interfaces,<sup>16</sup> which may explain such inconsistent effects on implant loosening.<sup>14,29</sup> In addition, the difference between weight as an absolute and BMI as a relative measure was often not considered.<sup>25</sup> Hence, in our study the influence of both variables on stem loosening was examined. Body weight had no consistent influence in either the cemented or uncemented THA groups, but in the former group BMI was associated with stem loosening. The risk of loosening increased significantly by 3% for each additional unit of BMI. Although the same trend was detected for uncemented stems, but was not significantly.

In our study, osteoarthritis was the most frequent diagnosis for THA and was defined as the referent. There was no significant difference between stem loosening risks for the specific diagnoses. Patients with rheumatoid arthritis have a lower loosening risk, whereas those with osteonecrosis and developmental dysplasia are at higher risk, and may also be due to difference in activity levels.<sup>13,25</sup>

To exemplify the influence of walking activity, the Charnley classification was used to indicate overall mobility. As the percentage of patients able to walk >60 minutes without any aids differs between the 3 Charnley groups,<sup>16</sup> it is a good proxy for activity level. The Charnley class B (decreased level of mobility) appeared to reduce loosening risk, although significance was only evident in the cemented THA group.<sup>10</sup> However, others have reported no association between Charnley classes and prosthesis survival.<sup>29</sup> More specific assessment of function and activity is therefore needed.

## CONCLUSION

The cause of stem loosening is multifactorial, and it is difficult to measure the contribution of each factor. In our matched case-control study, advanced age, female gender, and Charnley class B (as a proxy of reduced walking activity) had a protective effect on survival of cemented stems, whereas increased BMI was a risk factor. The mode of stem fixation (cemented or uncemented) should be carefully selected in different patient groups.

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